MODULE 4
VERTICAL WIND SHEAR

OBJECTIVES

At the completion of this module, the student will be able to:

1) Identify the two types of vertical wind shear;
2) Describe the effects of wind shear on thunderstorm development; and
3) Illustrate how a veering wind profile can induce rotation in a thunderstorm.

Previous discussion has focused on the ingredients needed to produce thunderstorms and the mechanisms that set the development process into motion. We have shown that thunderstorms thrive in an environment that is unstable and that they feast on a steady diet of moisture. Further, they are prolific producers and transporters of heat energy. However, this energy is not realized and the available ingredients are useless unless some lifting mechanism "kick-starts" the whole development process. We have examined of number of these sources of lift.

SEVERITY FACTORS

The obvious question at this point is, "what causes a thunderstorm to progress from being ordinary to being severe?" The answer centers on two specific factors: extreme instability and vertical wind shear.

Instability is something that we have already discussed and in Module 10 we will look at measures of instability in the atmosphere. For this stage of our study, let's just say that severity is directly proportional to instability; the greater the instability, the better the chance that a thunderstorm will become severe. As we will see later, the reasoning behind this statement is rooted in the relationship between instability and thunderstorm updraft potential. In simple terms, the greater the instability, the stronger the updraft potential, and thus the more likely that a thunderstorm can support the production of severe phenomena such as large hail.

VERTICAL WIND SHEAR

Let's direct our discussion then to that other factor, vertical wind shear. It would help at this point to define just what is meant by the term **wind shear**. Wind shear can be defined as the rate of change of wind speed and/or direction (something that collectively is referred to as wind velocity) over a short distance. This distance can be in the horizontal direction or, in the case of this discussion, in the vertical direction. You will immediately notice something from our definition. Wind shear can consist of speed shear, directional shear, or a combination of the two. Figure 4-1 illustrates the various components of shear. Notice in (a) that wind speed increases as you move up in the atmosphere and away from the frictional effects of the ground. There is no accompanying change in direction. This is a case of pure speed shear. You can illustrate the effects that such a condition would have on neighboring air by placing a sponge between your hands and holding them out in front of you. Now, move your left hand AWAY from your body while moving your right hand TOWARD your body. The result is a highly distorted shape to the sponge. The sponge has undergone a shearing. This same sort of shear would be experienced by just moving the left hand and keeping the right hand still.

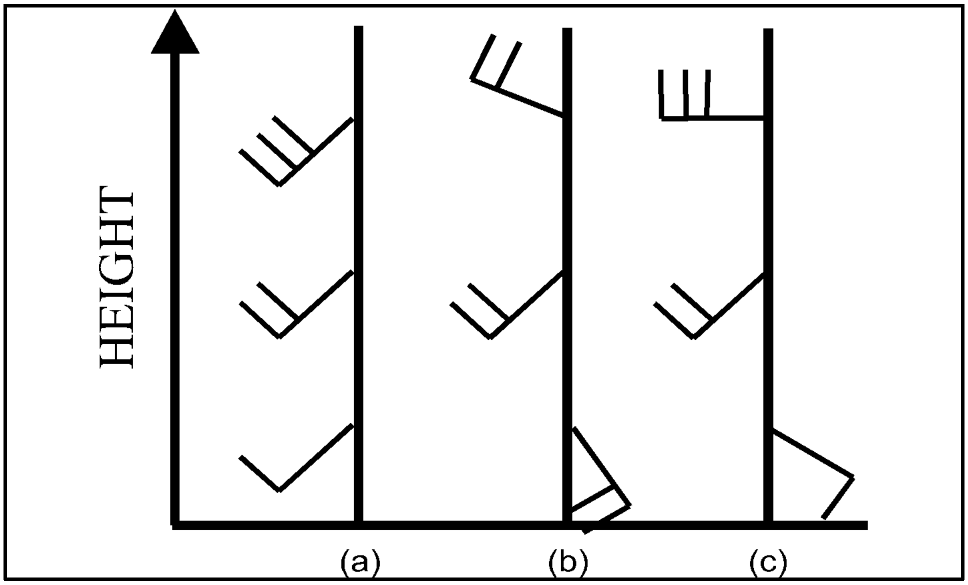

Figure 4-1: Illustration of the types of wind shear: (a) speed, (b) directional; and (c) combination speed and directional. Wind arrows indicate the direction from which the wind is blowing with each barb equal to 10 knots of speed.

The situation in (b) describes directional shear. The speed remains constant as we move away from the earth's surface, but the wind direction changes, in this case, in a clockwise fashion (something meteorologists refer to as **veering** of the wind). To illustrate this condition, again place the sponge between your hands with your left hand on top and your right hand underneath it. Now, move your right (underneath) hand AWAY from your body and, at the same time, move the left (upper) hand to the right ACROSS your body with the SAME force . You will see that the sponge is again distorted, but, while difficult to see, the resultant force is not in the direction of either individual force, but at a 45 degree angle to each.

Finally, in (c) we have both types of shear contributing to the total vertical shear: wind speed is increasing with height and, at the same time, changing direction as we go upward. This condition exists more often than you might think in the lower part of the atmosphere, but may not exist simultaneously with other ingredients needed for thunderstorm development. Don't even try to simulate this complicated condition with a sponge; you might injure yourself!

SHEAR PROFILES

Not only will the existence of vertical shear promote the transition of an ordinary thunderstorm into one that produces severe phenomena, but it will contribute to the type of severe thunderstorm that may develop. It is important to consider a few profiles of sheared environments.

In a low-shear profile (see Figure 4-2), wind direction or speed changes little as we move upward through the atmosphere. Moist air is carried upward and condenses into cloud droplets and eventually raindrops heavy enough to fall back toward earth. In the absence of shear, much of the rain falls back into the region of updraft. The resulting interference eventually cuts off the inflow into the storm and weakens the updraft. Without the necessary input of warm, moist air, the storm will find it difficult to survive.

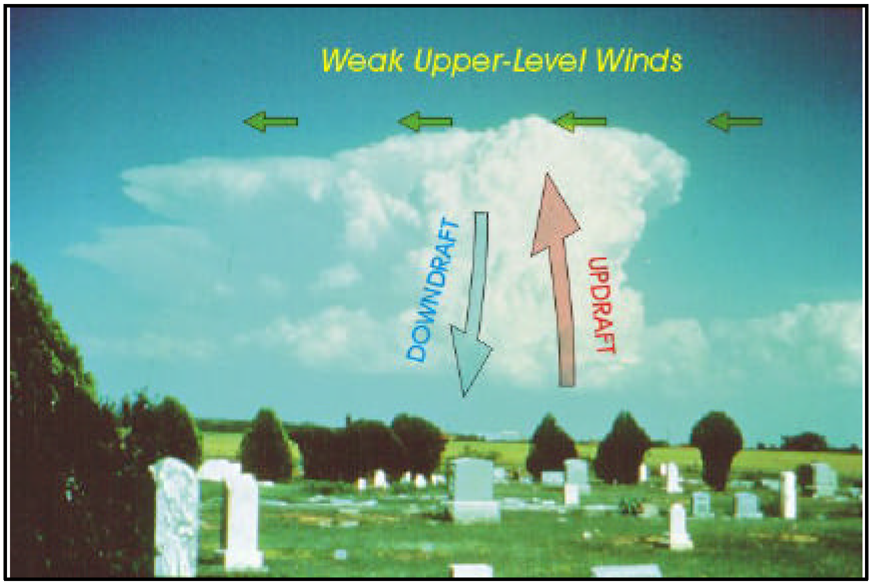

Figure 4-2: Thunderstorm in a low-shear environment.

An extremely unstable atmosphere can overcome some of the negative aspects of this weak-sheared condition. Updrafts will be stronger and support higher liquid water content within the growing cloud. This, in turn, will lead to the storm being a more prolific rain-producer. Storms that produce flash flooding often occur under conditions of weak shear and high instability.

Conditions in which there exists moderate speed and/or directional shear favor development of strong, occasionally severe, thunderstorms. What severe weather occurs is usually in the form of large hail brought about by a stronger updraft within the storm or damaging straight-line surface wind. The shear, however, is usually not of the magnitude to produce the rotation needed to spawn tornadoes, at least long-lived ones.

In a moderately-sheared environment, the updraft is slightly tilted. This allows for precipitation that forms to fall downstream of the updraft. This somewhat prevents the development of an interference zone between the updraft and precipitation-induced downdraft. The storm is able to continually ingest the warm and moist air it needs to sustain itself for a longer period of time.

The moderate-sheared environment supports a type of storm structure known as multi-cellular (more about this later). For now, just know that multi-cellular means that a storm consists of a number of updraft/downdraft regions (cells) in differing stages of development. Eventually, one cell weakens as another cell becomes dominant.

Finally, we must consider the highly-sheared environment (see Figure 4-3). In an atmosphere of extreme instability, the severe weather forecaster is faced with the most potentially dangerous conditions. When the wind veers sharply in the lower 6,000 feet or so of the atmosphere and strong mid to upper-level wind flow is moving across the storm genesis region, the environment is conducive to supporting a long-lived and particularly violent storm known as a supercell.

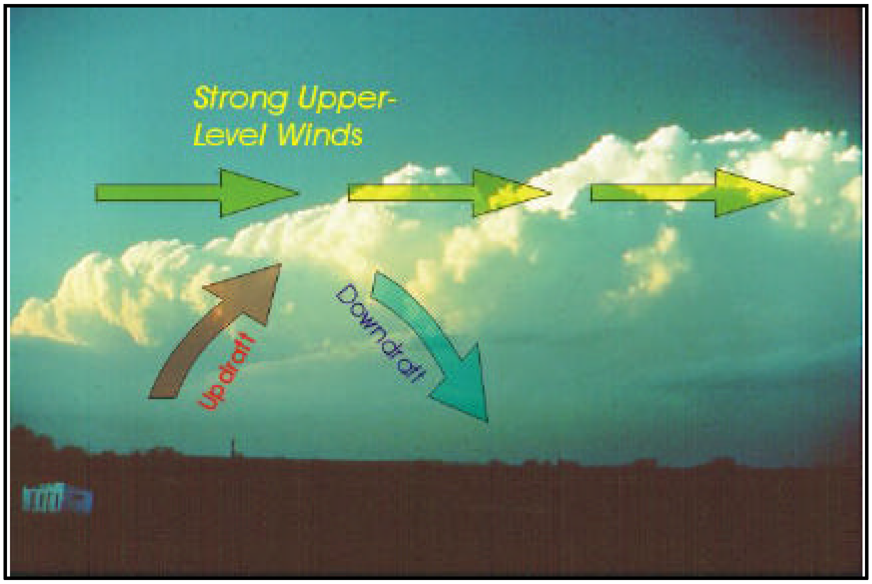

Figure 4-3: Thunderstorm in a high-sheared environment.

However, if the instability is not of the magnitude to support intense updrafts, strong shearing will literally tear any developing cloud towers apart and storm development will be unlikely.

Extreme instability in a strongly-sheared environment will produce updrafts that may exceed 80-90 mph (40 m/s)! An updraft this strong is capable of suspending hailstones the size of softballs. Updrafts this strong can and often do penetrate the upper-level stable region known as the **equilibrium level**, which usually marks the upper reaches of the thunderstorm cloud. Finally, observations show that extremely strong updrafts of the type associated with supercell thunderstorms often bend back into the strong environmental wind in the upper levels. With wind at the 30,000 to 40,000 foot level on the order of 100 mph (50 m/s) or greater, it would take quite an updraft to be able to move upwind.

One feature that will be discussed again later is the generation of rotation in tornadic storms. Directional wind shear plays a major role in this process. To illustrate, consider southeast inflow into a storm near the surface with southwest wind entering the storm at about 5,000 feet. This clockwise turning of the wind with height is referred to as a **veering** wind profile. (If the wind turned counterclockwise with height (i.e., south at the surface to east at 5,000 feet), then the wind is referred to as **backing** with height.) Similar to the demonstration with the sponge, the air will be sheared with horizontal rolls developing. These rolls enter the storm and are subsequently tilted upward by the storm's updraft. Under the right conditions, this "vortex tube" could establish a persistent rotation within the storm. Figure 4-4 shows the developmental process.

Figure 4-4a: Schematic of how a rotating updraft develops. Part 1 - strong veering winds produce horizontal vortices in the lowest mile of the atmosphere.

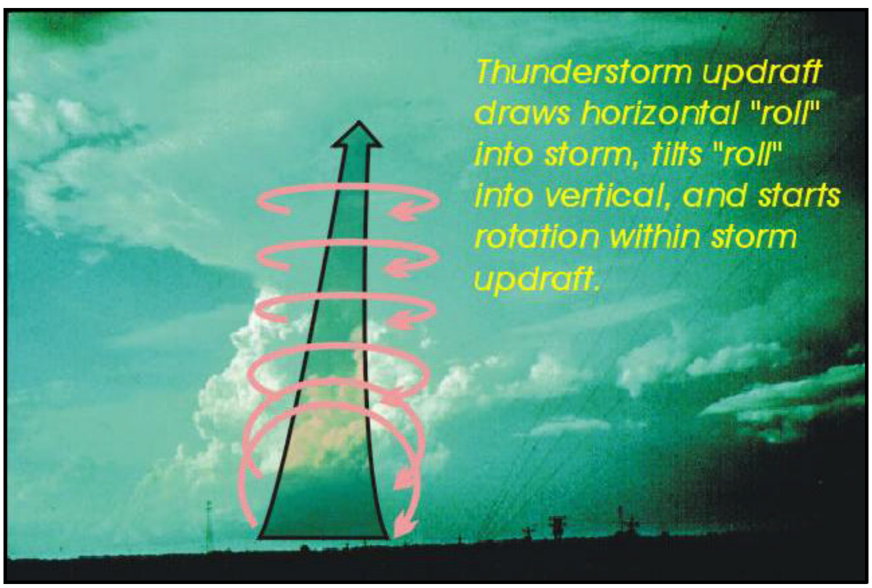

Figure 4-4b: Schematic of how a rotating updraft develops. Part 2 -- storm's updraft ingests the horizontal "rolls" and tilts the rolls into the vertical.